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Journal of the
IRRIGATION AND DRAINAGE DIVISION
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ECONOMIC EVALUATION OF WATER

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ABSTRACT

The dominant force in developing water resources in the west has been land irrigation presupposing that the maximum economic benefit would result from the maximum occupancy of land by people. The rise of industry as a major factor in western economy has rendered this criterion inadequate. A broader policy basis is needed by which presently unappropriated water is allocated to various beneficial uses in such a way as to produce the greatest economic yield.

INTRODUCTION

It has been said that the people of the semi-arid west above all others in the United States know the value of water. Certainly in this region the line which "divides the desert from the sown," the rich land from the wasteland, is a water line unmistakable to the most casual observer. Here in the Arizona, at least one past civilization disappeared because it ran out of water. Today almost every citizen of the southwest is aware that his present and future economy depends upon water, and that without it he too may be one with the Hohokam—"The people who are gone." Thus in broad terms the economic worth of water is self-evident.

In specific terms, however, the value of water is so obscured by a fast array of human attitudes that any basis for its economic evaluation becomes elusive in the extreme. He who searches for such a basis is at once confronted with conflicting evidence. Sometimes water is a symbol of charity—a "gift of the gods." Sometimes it is the exclusive property of the uncharitable. On the simple basis of ownership of real estate, some citizens have "rights" to

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water beyond those enjoyed by other citizens. Under some conditions this "right" requires that others must furnish water at a price agriculture can "afford to pay." Always water is the cheapest commodity on earth, being transported long distances, filtered, sterilized, and delivered into our homes for five cents a ton.

The very cheapness of water leads to a lack of understanding of its value and to a confusion of its dollar and cents cost with its worth as an economic resource. More important perhaps is a vast roadblock to thinking about the economic value of water which arises from historical association of the whole matter of water rights and water value with public land policy rather than with the effects of water usage on the economy of the nation, region, or state.

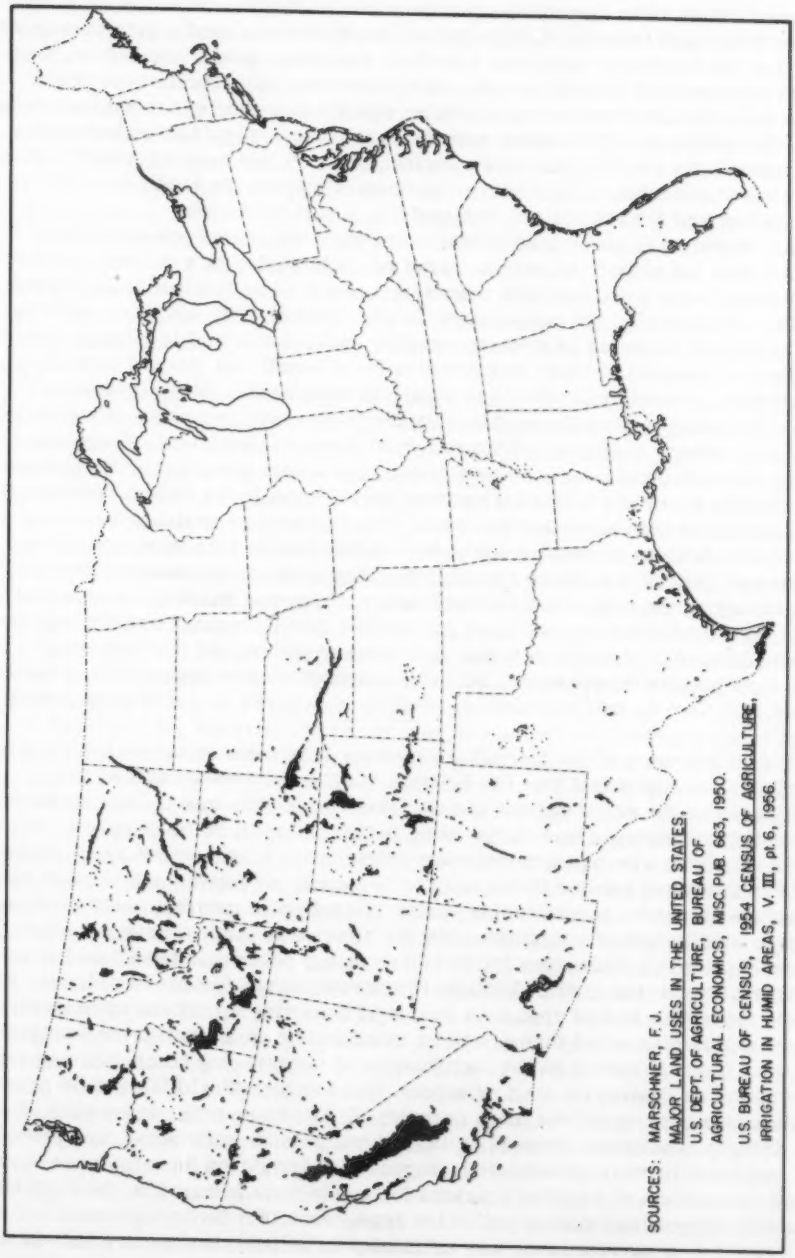
Development of Western Water Under Federal Policy

Ever since land hungry pioneers trekked across the prairies only to discover that arid western land, unlike that of the humid east, could not be cultivated by mere breaking of the sod, capturing and redistributing the nation's meager water supply has been a major objective of national policy. That the dominant force in the development of water in the west has been the provision of irrigation supplies is evident in land and water statistics which reveal that although the 17 western states comprise 60 per cent of the nation's land area, they contain only one-fourth of its water supply but 94 per cent of all its irrigated land (see Fig. 1). In terms of acreage the 1954 Census of Agriculture reports only 534,647 acres of irrigated crops and pasture in the entire eastern section of the United States, compared with 7,048,049 in California alone.

The affinity of land use and water use patterns is made more apparent by the striking contrast between eastern and western water use. In the 31 eastern states, where water supplies are more abundant and better distributed, industrial withdrawals account for approximately 82 per cent of the total, as against 3 per cent for irrigation. In the 17 western states, however, the situation is essentially the reverse, with 13 per cent going into industrial uses and 82 per cent into irrigation.

Specifically charged by Congress with maintaining agricultural production on western lands threatened with retrogression to desert, the Bureau of Reclamation has for more than fifty years dotted the region with water development works designed to reclaim land by impounding wet weather runoff and delivering it for irrigation. Displayed prominently on signs alongside these projects is a somewhat tranquil buffalo, the emblem of the Bureau's parent organization, the Department of the Interior. Except for a few surviving specimens preserved as living museum pieces, this symbol of the frontier has long since vanished. There are indications, however, that western water policy—whose basic tenets evolved out of the same frontier spirit which all but obliterated the buffalo—continues to be conditioned by vestiges of the same wastefulness characteristic of early settlement days. This inquiry, therefore, concerns the possibility that rigid adherence to past policies may aggravate contemporary problems confronting the rapidly growing southwest as the character of its economy undergoes transitions and as alternate uses of water compete for scarce supplies.

Any search for a basis on which to judge the economic worth of water must necessarily begin with a study of the factors which have conditioned water policy in the past, which traditionally have guided such policy, and which tend



SOURCES: MARSCHNER, F. J.
MAJOR LAND USES IN THE UNITED STATES,
U.S. DEPT. OF AGRICULTURE, BUREAU OF
AGRICULTURAL ECONOMICS, MISC. PUB. 663, 1950.
U.S. BUREAU OF CENSUS, 1954 CENSUS OF AGRICULTURE,
IRRIGATION IN HUMID AREAS, V. III, pt. 6, 1956.

FIG. 1 - IRRIGATED LAND IN THE UNITED STATES

to govern today's thinking about the use of water resources. Evolving under obscure intent in an agrarian economy, water resources development policy in the west has, from its very beginning, been tied to a land policy presupposing that the maximum economic benefit to the nation would result from maximum occupancy of land by people. At a time when most Americans were self-sufficient farmers and agriculture was the mainstay of the nation's economy, this policy of underwriting widespread disposal of public lands for development into small farms was a logical goal. Policy makers broadly evaluated water in terms of its contribution toward making the landless self-supporting and toward settling and unifying a vast land area.

As westward expansion accelerated and settlers came upon more arid areas, they found that the soil could not be cultivated with available rainfall. Confronted with a predicament unforeseen in a land settlement policy based on the assumed climatic homogeneity of the country, they sought to overcome the limitation imposed by western aridity. Individually and in groups, western farmers attempted to store and divert natural runoff, but limited capital generally confined their efforts to minor developments. More extensive projects based on investment financing quickly proved incapable of yielding a profit to private capital in all but the most favorable locations. Hence as water demand increased and more distant and costly developments were envisioned to store and deliver irrigation water, appeals for federal assistance began to be heard throughout the west. The tendency to evaluate water resources chiefly as an implement of land settlement had its inception in the response of Congress to these appeals. Seeking to facilitate western expansion by remedying the region's water deficiency, Congress enacted a number of laws (principally the Desert Land Act of 1877, the Carey Act of 1894, and the Reclamation Act of 1902) to foster irrigation projects. At first these encouraged private development, but later, when it became apparent that capital costs could not be self-liquidating, publicly-sponsored projects were authorized.

Direct entrance of the federal government into water resources development necessarily meant that the function of allocating water was no longer contingent on the price system and that this commodity was to be distributed according to whatever was declared by public policy to be its best use. Yet no clear economic assumptions underlay federal policy. As an auxiliary adjunct of land policy not related to any defined economic objectives and first designed to induce extensive homesteading, water allocation in the west could be based only on a principle of widest possible distribution to land. Throughout the years economic justification for this unwavering policy has been found in a variety of short-run goals. Initially the development of water to reclaim public lands was looked upon as a means of achieving a mixture of conservation and family-sized farms, and as an economic stimulant to the western region. Later it rested on the justification of encouraging home-building and preventing or destroying land monopoly. During both World Wars food production was considered the main purpose. In the intervening depression, curing drought conditions, preserving land already under cultivation, and providing employment were accentuated. Support for irrigation has also been advocated as a means of creating markets for goods manufactured in the east, but it is now approached mainly within the framework of a food program.

Irrigation of private lands was originally an incidental objective but eventually, when public lands had largely passed into private ownership, the distribution of publicly-developed water supplies to established enterprises became predominant. In rationalizing this change in concept, irrigation development

was likened to roads and other public works in which public purpose is involved. That the value resulting from the expenditure of public funds becomes the property of private individuals, however, has not seemed to weigh heavily in making federal appropriations.

Since the depression of the 1930's, criticism of national agricultural policy has been increasingly severe. While critics of indiscriminate extension of land into additional agricultural production have generally argued that increased acreage is not economically warranted, until recently little consideration has been given to the possibility that such a policy might also result in wasteful commitment of limited water supplies. Only in the past few years, when the nation's total water supply has been measured against potential long-range demand, has such apprehension been expressed. Beginning with the 1952 report of the President's Materials Policy Commission and subsequently typified in periodic policy statements of organizations such as the Engineers Joint Council, greater awareness of the intrinsic value of water has been urged.

It becomes apparent then, that federal water policy offers little basis on which to judge the economic value of water because of its historic orientation toward stimulating the expansion of irrigated agriculture. A fundamental premise of resource allocation through the price system is that the entire cost of producing a commodity be reflected in its market price. Under federal policy, however, the price of water is not related to the cost incurred in providing it. Rates for municipal and industrial water are set according to the market. Revenue from power, the financial backbone of multiple purpose projects, is also based on market value. But the price of irrigation water is calculated after all agricultural production costs except water have been met, and if the price is considered greater than farmers can pay, revenues from power and municipal and industrial water sales are used to make up the difference.

In underpricing water to carry out land use objectives, federal policy has been an inflexible substitute for supply and demand. As the agent for channeling the utilization of this resource to producers, public policy has encouraged use which is uneconomical in the sense that it has led to the apportionment of water in a manner unrelated to the relative yields that might result from its use as a factor of production. When industrial growth burst forth, water policies founded exclusively on a concept of maximum land reclamation were rendered ill-adapted to the changing pattern of western economic development. Industrialization stimulated a trend toward urbanization and a shift of population from farms to cities. Consequently urban water demand persistently increased and it became possible to put important amounts of water to uses yielding a higher return and creating wider economic benefits than irrigation. Clinging to tradition, however, federal policy tended to stress the application of water to land, and in turn, to perpetuate an agrarian economy in the west. Thus, it became a faulty gauge of the economic value of water.

In summation, as a governing mechanism for controlling the use of water, federal policy has not reflected the changing scarcity of this resource, or its relatively utility under alternate uses in water short areas. A compelling corollary of this inadequacy stems from the controlling influence water distribution exerts on economic development. As the pressure of competing beneficial uses increases, policies which fail to take into account the relative worth of water resulting from alternate beneficial uses in different areas may conceivably hamper sound economic growth. However appropriate a land

settlement policy may have been to frontier conditions and to the nation's early development, it is now a tenuous framework for an economic evaluation of water based on optimum use.

Factors Tending to Perpetuate Traditional Concepts

While federal development of water in the west may continue to be more federal than state controlled in most states except California, all of the west and especially the southwest has become increasingly concerned with the limitations water places upon its economic growth. In some instances this concern has outcropped as a demand for a greater share of the region's limited water in order to expand an existing agrarian economy. In many cases, however, state and local leaders have begun to consider seriously the possibility of greater economic return from dedicating an important amount of a scarce and in many cases declining water supply to industrial uses. Thus an economic evaluation of water takes the form of comparing the wealth producing capacity of water in agriculture and in industry. Furthermore, in many cases the inquiry goes even further, into the type of industry capable of producing maximum economic return from a given amount of water. Hence there is ample reason to believe that better criteria for the economic evaluation of water would be welcomed by those responsible for formulating water policy in western states.

In the search for a basis for such criteria it becomes important to examine the forces, aside from the demand for agricultural products occasioned by population growth, tending to foster an ever widening extension of irrigation facilities essentially as the exclusive goal of water resources development; and to make some comparisons of the wealth producing capabilities of certain amounts of water in a situation of scarce supply. Four factors are of primary significance. These are financial; land classification; legal; and political considerations.

Financial Factors

Traditional federal policies for financing irrigation works have tended to obscure the value of water. In the process of drawing upon diffused financial sources to provide federal reclamation works, traceable benefits have accrued to some individuals or groups to justify requiring them to pay proportionate charges. However, as an outgrowth of historical policy assumptions, federal practice has been to subsidize irrigation water users. Subsidization from general tax revenues results from extending capital cost repayment periods under interest-free provisions and from the assignment of costs to other benefits in multiple purpose development. When capital costs or the price of water is subsidized, certain property owners may realize increased values without paying accordingly. This procedure violates long-established principles of assessing users of local utilities according to benefits received. It is estimated that the total subsidy to an irrigator owning 1,000 acres of land in the Central Valley Project of California approximates $577,000 over a 50-year period, or $11,540 per year.

Whether state-sponsored water development projects should follow the financing pattern established by the federal government for reclamation works is a policy question of paramount importance in view of the very magnitude of the expenditure involved. This is especially true in California where plans

for state development of water resources may within two decades cost as much as the total federal budget for such work in the entire United States, and ultimately, more than expended by the federal government on water development in the past one hundred years.

Inadequate Classification of Land

The suitability of land for irrigated crops is largely dependent on inherent physical characteristics of the soil, topography, climate and drainage conditions. These factors are subject to little modification and they must be carefully evaluated when determining whether the potential earning power of land warrants the provision of irrigation water.

Deficiencies in land classification have been the source of some of the most costly errors in water distribution. In some cases failure to classify land adequately according to its productive capacity has tended to encourage the extension of irrigation agriculture beyond wise limits. This inadequacy runs through the entire course of federal land policy and, in relation to water development, it is with us yet today on both state and national levels.

Land classification in a variety of forms is currently undertaken by many governmental agencies. These surveys are conducted independently on a functional rather than a real basis and are tailored to the requirements of the agency. They differ according to the capacity of the agency and according to whether they are prepared by soil scientists, agronomists, foresters, geographers, highway engineers, urban planners, or tax assessors.

Excluding agencies to whom analysis of soil quality is incidental to their major function, there are at least a half dozen public agencies which compile data on the irrigation potentialities of land in California. There are varying degrees of uniformity in the classification methods of these agencies.

Land classification surveys are usually differentiated on the basis of three scales denoting the accuracy and amount of detail. A reconnaissance survey is a general outline of land features of conspicuous importance in planning irrigation. A semi-detailed survey involves a thorough examination of lands likely to be devoted to intensive agricultural use, while marginal use areas are only briefly studied. Arable and non-arable lands are mapped with considerable accuracy, but the boundaries between different classes of arable lands are not delineated with the same degree of accuracy as required in a detailed classification. A detailed survey involves an examination in sufficient detail to permit an accurate appraisal of the potential utility of the land.

The extent to which land classification has influenced water resources development policy and hence contributed to basic criteria for the economic evaluation of water may be judged from the situation in California. Here, although the Bureau of Reclamation has engaged in a limited evaluation of land in specific areas where water development is proposed, the Soil Conservation Service, in cooperation with other agencies, has attempted to undertake a statewide survey only since 1934. Progress on the survey has been necessarily slow and it is expected that at the present rate fifteen years will be required to cover the whole state.

Of California's 100 million acres, it is estimated that 60 to 70 per cent are not topographically suited for irrigation or urban use. Of the remaining 30 to 40 million acres, the Soil Conservation Service estimates that approximately 12 per cent have been surveyed in detail. During 1949 and 1950 the Soil Conservation Service and other agencies completed a rapid coverage

reconnaissance land and water inventory of each county in the state. From this survey the following tabulation of land resources resulted:(1)

TABLE 1

California Land According to Suitability for Cultivation

	Land Capability Classification	Percent of Total
Suitability for Cultivation (16.5 percent)	I	1.6
	II	5.1
	III	5.6
	IV	4.2
Unsuitable for Cultivation	V	0.3
	VI	16.3
	VII	30.4
	VIII	32.9
Unclassified		3.7
Total		100.0

Significantly, Table 1 indicates that only 6.7 per cent of the land appraised in the Soil Conservation Survey is in Classes I and II, i.e., land with little or no limitations. In comparison a relatively small state such as Iowa has at least 18 million acres of excellent soils. With more than 7 million acres irrigated in 1954, it can be assumed that virtually all the prime agricultural land with high capability characteristics is under cultivation in California.

Indicative of a changing concept in irrigability, however, is the following contrast. When the national program of purchasing infertile lands was getting under way in 1934, the National Resources Planning Board, as part of an inventory of land productivity classes in the United States, estimated that there were 4,746,632 irrigable acres in California. Land productivity was broken down in this manner:(2)

TABLE 2

California Land Classified According to Productivity by National Resources Planning Board

Classification	Acres
Grade 1 - Excellent	46,976
Grade 2 - Good	478,297
Grade 3 - Fair	3,364,517
Grade 4 - Poor	13,380,327
Grade 5 - Incapable of tillage	82,347,163

In the current California Water Plan by which the state proposes to develop its own water resources a gross area of about 20,000,000 acres is classified as suitable for irrigated agriculture, of which it is estimated 16,200,000 acres

could be irrigated in any one season under ultimate conditions of development. Much of the land area deficient in water lies in the desert areas south of the Tehachapis and it is presumably relative to that area that many of the most difficult decisions on water policy will have to be made in the coming years. It is in these decisions that it will become clear whether future water developments are to be based on traditional land policy, or on some new basis in which alternate uses of water enter into the final arbitration.

In cases such as this the absence of a standardized method for evaluating the irrigability of land becomes a critical weakness because it opens the way for widely varying interpretations of potential productivity, especially of land which is neither extremely good nor extremely bad. A good example of the magnitude of this problem is illustrated in Fig. 2 which compares proposed water service areas in California with a generalized Soil Conservation Service map indicating dominant land capability.

Clearly land classification has not weighed heavily in the justification of water resources development and hence its lack has been another factor obscuring the economic worth of water. In the absence of any criterion based upon land classification water deficiency in an area is often interpreted as justification for bringing water to such land. However, such a water deficient area may well lack other elements conducive to agricultural or urban development, and, under a principle of optimum use, greater economic gains might be realized by deferring development in favor of furnishing additional supplies to other areas of lesser water deficiency but with better growth potential.

The possibility of narrowing the area of discretion in determining water distribution by adopting land classification data as governing criteria is seemingly impeded by a conflict with judicial protection or property rights. Property holders have asserted that disqualification of land from water delivery through the adoption of minimum development standards based upon the productivity of the soil violates fundamental constitutional guarantees, and that denial of water on the basis of land classification is tantamount to the confiscation of property values. Where prior water rights are involved, legal doctrine provides that the owner may make use of the water so long as he is not wasteful. Because "wasteful" is broadly defined, however, it may be possible for a land owner with early filings to a considerable amount of water to extend service to relatively unproductive lands even though higher economic returns are possible from competing irrigation or urban uses elsewhere. In this connection, an abuse sometimes known as "show-horning" occurs. This involves the exertion of political pressure to secure the inclusion of less productive land adjacent to fertile areas when an irrigation district is formed or when water is distributed. Since "ability to pay" is a criterion based on land capability, the inclusion of poor land affects the extent to which irrigation is subsidized. It may properly be asked to what degree should subsidized water be used to extend irrigation to land capable of yielding crops in only marginal amounts? Carried to its logical conclusion, the ability to pay concept suggests that water rights for worthless land should entitle the owner to free water.

Legal Factors

The expansion of irrigation facilities in an uneconomic manner, in the sense that they do not pay their way, is partly attributable to the vagueness of public policy and the obsolescence of the legal doctrines used to evaluate alternative claims to water. Unlike land, which is converted to higher

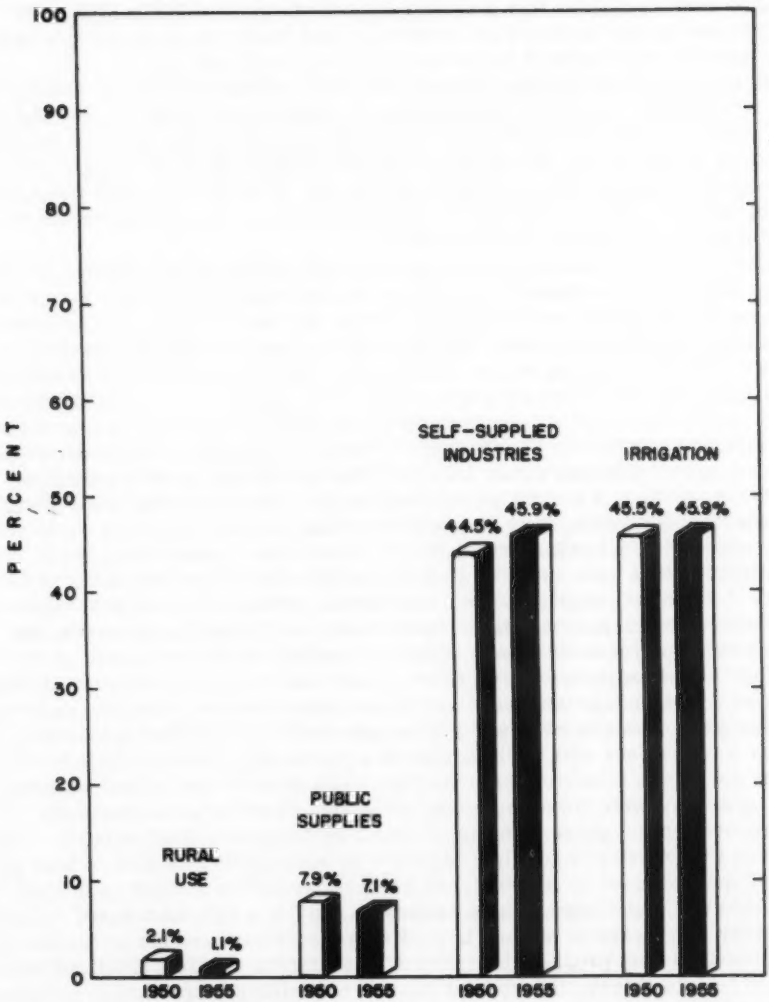


Fig. 2—Relative Withdrawal of Water in United States, 1950 and 1955

economic uses with relative fluidity, water use remains somewhat inflexible under state laws governing its allocation. Once a right is secured it becomes a property right inviolate for all time. Water rights in California, for example, may be secured by the time honored "riparian" concept, or by the "prior appropriation doctrine," inherited by irrigators from the Gold Rush miners, who refused to recognize the riparian concept and substituted instead one of "first use, first in right." As applied to newly-developed water, the appropriation doctrine contemplates a progressive reservation for future use until a condition of maximum utilization is reached. The key to determining whether the most productive uses will prevail lies in the power to allocate water rights and to regulate existing withdrawals. If public policy sanctions such an approach, the agency with discretion to grant prior rights is in a position to implement a broad planning function. However, from an economic standpoint, existing doctrines for evaluating alternative claims to property rights to water are extraordinarily nebulous.

Legal factors may vary considerably from state to state but it is extremely doubtful that in any state they provide either a clear cut basis by which the economic value of water in alternate beneficial uses may be judged, or create an administrative arrangement for carrying out water policy which provides for the making of such judgments.

Political Factors

Political factors bearing upon the economic evaluation of water concern the rivalry of numerous competing agencies each having limited objectives, and with pressure groups representing a combination of organizations which further irrigation development through legislative bodies strongly predisposed toward agricultural interests. The time may well be approaching when farmers are able to select the agency from which they purchase water. Should this occur the competitive position of any state which develops its own water resources is somewhat vulnerable because it must be able to sell water at a price comparable to federal agencies which have financing advantages and lower costs resulting from earlier development of more productive sites.

To an almost exclusive degree political factors are reflected in the policy of maximum application of water to land. More than any other factor, perhaps, they account for an uneconomic extension of irrigated agriculture. In quite recent years, however, some very bitter dissension over water rights has entered the political arena. On the surface these often seem to be quarrels between water-surplus and water-short areas, but on closer examination industrial-urban demands may be found increasingly to be in conflict with the traditional concept of water resources development to provide irrigation water at a price agriculture can "afford to pay."

Some Economic Implications

Classical economic theory holds that the price system, operating in a competitive market, efficiently allocates resources according to the maximum value produced. Supposedly, through this interplay of competitive forces in the free market, uneconomic employment of scarce resources gives way to uses in greater demand. While there are many deviations from the classical concept in the national economy, rarely has the interaction of supply and demand had less to do with price determination than in the case of water.

Once the assumption that the value of water to agriculture should be related to what agriculture can "afford to pay" was established, public policy rather than the market economy became the control mechanism for allocating diminishing water supplies to alternate producers.

Although the objectives of public policies on the development, allocation, and pricing of water have not always proceeded from explicit economic assumptions, they have generally been tied to the notion that the maximum economic benefit to the nation would result from widespread land utilization. Replacing supply and demand as a determinant of resource allocation to producers, public policy has tended to underprice agricultural water to effectuate this historic premise. As previously noted, this is accomplished in several ways. Agricultural water is subsidized through increased power charges to industry, the high value product of which is less sensitive to the cost of water power; and through greater cost of electricity to domestic consumers, to whom electricity is in any case a rather cheap commodity. In addition, municipal and industrial water users are charged with market price and surplus revenues are diverted to pay irrigation costs. Further subsidization has been made available from general tax sources by assigning what many believe to be an undue portion of capital costs to less tangible public benefits.

As a governing mechanism for controlling the use of water then, public policy does not necessarily reflect the changing scarcity of this resource or its relative utility under alternate uses. A compelling corollary of this inadequacy stems from the monitoring role of water use on economic development. As a factor of production, as in manufacturing and agricultural use, or an unwithdrawn substance as in recreational use, water has a prime, albeit indirect, influence on the magnitude to which employment, purchasing power, and tax revenues are generated. At the same time distribution of water to urban and agricultural areas molds the land use makeup of the state, a key aspect of its economy. In a broad sense then, water exerts a controlling influence on the capacity of a state's economy to support its people. To this extent the use of water by various segments of the economy has measurable economic value, and public resource policies accentuating one form of water use or expansion of one geographical area as against another may tend to enhance or retard economic development. While not as far-reaching in economic effect as federal monetary policies or the allocation of defense contracts, state water policies—because they are directly involved in the production process—may be even more useful in implementing economic development than land use policies have been for municipalities.

Although public policy influences the volume and nature of water use as well as the course of economic development, economic and water use developments growing outside the framework of narrow public water policy can in turn come to exert great pressures upon that policy. This is essentially what has taken place in California. There existing uses of water are relatively fixed under a doctrine of granting irrevocable rights to prior users. The state, however, is empowered to select future users of the unallocated supply developed by new projects, and it is in this connection that the previously ignored urban and industrial users have lately begun to demand rights equal to those of land. Whether allocation of water not already committed through prior rights will be construed in terms of economic productivity remains to be seen, but it is this possibility and the need for policy concerning it that makes urgent a search for criteria by which the economic value of water may be determined. The problem is by no means unique to the state of California

even though that state may have certain geographical and climatic advantages which make the extension of irrigation more than normally profitable. In varying degrees the entire western part of the United States is confronted with the problem.

The emergence of competitive beneficial uses in a traditional agrarian economy can not be ignored, however disturbing it may be to traditional concepts. Urbanization is a characteristic of modern times and some idea of the scope of its implications in the west and southwest may be drawn from California's experience even though that state may have come to face the problem sooner than some of its neighbors.

A comparison of Figs. 3 and 4, based on U. S. Geological Survey data(3) indicates that the percentage of total water used by industry and agriculture departed significantly from the national pattern in the period between 1950 and 1955. Whereas the relative distribution of both uses remained virtually unchanged in the nation, in California irrigation declined 17.2 per cent, while self-supplied industrial use, including use of saline water, increased 19.6 per cent.

Table 3 reflects the balance between the aggregate volume of industrial and agricultural withdrawals for the nation as a whole, and shows that a similar percentage increase occurred in both between 1950 and 1955. However, in California, although irrigation use underwent a 12.6 per cent increase and remained predominant during the period, fresh and brackish industrial withdrawals rose 2,050 per cent. More striking perhaps is the fact that while the ratio between irrigation and industrial use in 1950 was 68.5:1, in 1955 it was but 3.8:1.

TABLE 3

Withdrawal of Water, United States and California, 1950-1955
(Million Gallons per Day)

Use	United States			California		
	1950	1955	% Change	1950	1955	% Change
Rural	3,564	2,400	-32.7	280	111	- 41.6
Public Supplies	13,640	17,000	+19.8	1,300	1,290	0
Self-supplied Industrial	77,216	110,000	+29.7	295	6,280	+2,050
Irrigation	78,900	110,000	+28.2	20,450	23,025	+ 12.6
Total	173,320	240,000		22,323	30,595	

Personal Income

The aggregate income received by the residents of California from all sources determines their ability to spend, to save, and to pay taxes. Personal income is thus a good indicator of the state's economy as a market for the sale of goods and services whose production provides employment. Trends in personal and per capita income are perhaps the key measures of economic expansion potential.

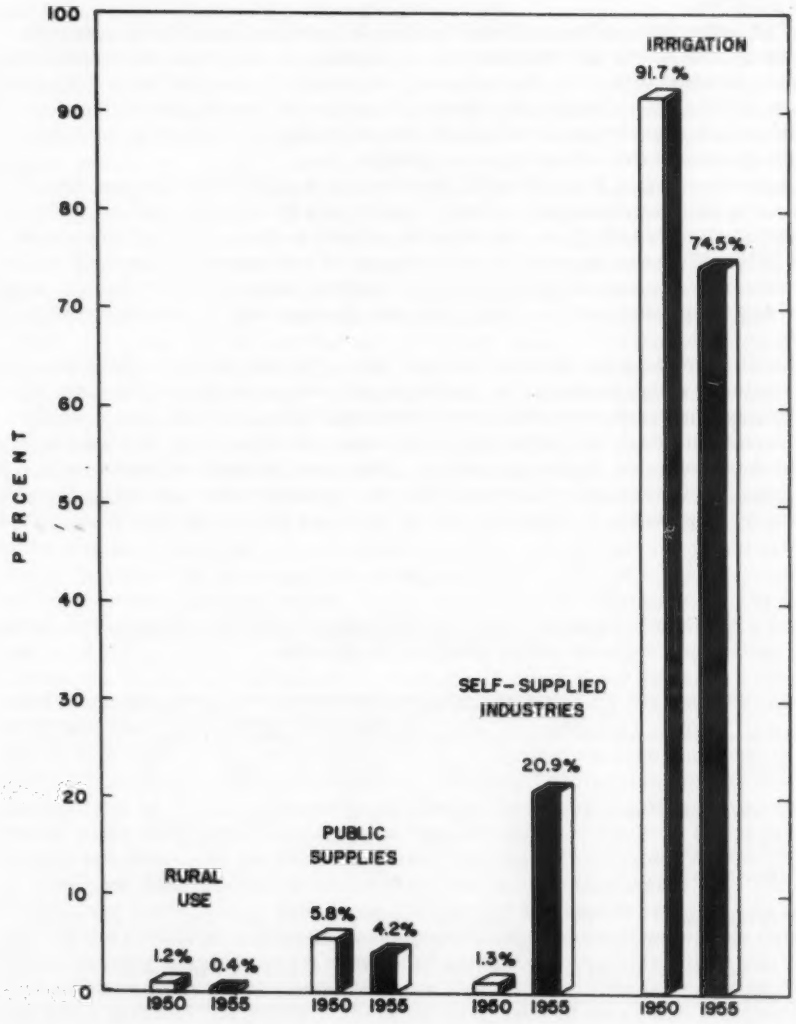


Fig. 3—Relative Withdrawal of Water in California, 1950 and 1955

Amounting to approximately $30 billion in 1955, personal income in California ranked second only to New York, which had $36 billion. The rising trend of the state's income is indicated in Table 4.

TABLE 4

Changes in California Income by Total and Percentage of United States, Selected Years, 1929-1955

	1929	1940	1946	1950	1953	1955
Total income (millions of dollars)	5,502	5,839	16,084	19.627	26,642	29,438
% of United States	6.42	7.43	9.15	8.70	9.41	9.70

Between 1950 and 1955 the state's personal income rose approximately 50 per cent. During that period the pattern of growth differed markedly from the nation as a whole. While the percentage of total income from manufacturing in the United States increased only 1.4 per cent, California's income from this source increased 7.4 per cent. Table 5 depicts the relative extent to which the three water-using segments of California's economy directly accounted for personal income received by individuals in the state in 1955. Wages and salaries accounted for two-thirds of the income received by the state's residents. Only one-eighth came from proprietorships including farming.

TABLE 5

Percent Distribution of Income by Industry, 1955

	U. S. Average	California
Farms	9.77	6.0
Manufacturing	25.73	25.1
Services	10.95	13.2

Role of Manufacturing

The magnitude of manufacturing's increasing importance in the state's, as well as the nation's economy, during the past 25 years is indeed striking. Table 6 shows that in 1955 there were only seven states in the U.S.A. in which manufacturing did not account for more personal income than did farming, and only thirteen in which farming exceeded services. In the period 1933 to 1955 the increase in personal income from manufacturing in California was 3.5 times that of farms and 2.5 times that of services.

These increases underlay a marked transition in the state's employment structure. Undergoing a 58 per cent increase from 1950 to 1956 (Fig. 6) manufacturing has become California's chief source of employment.

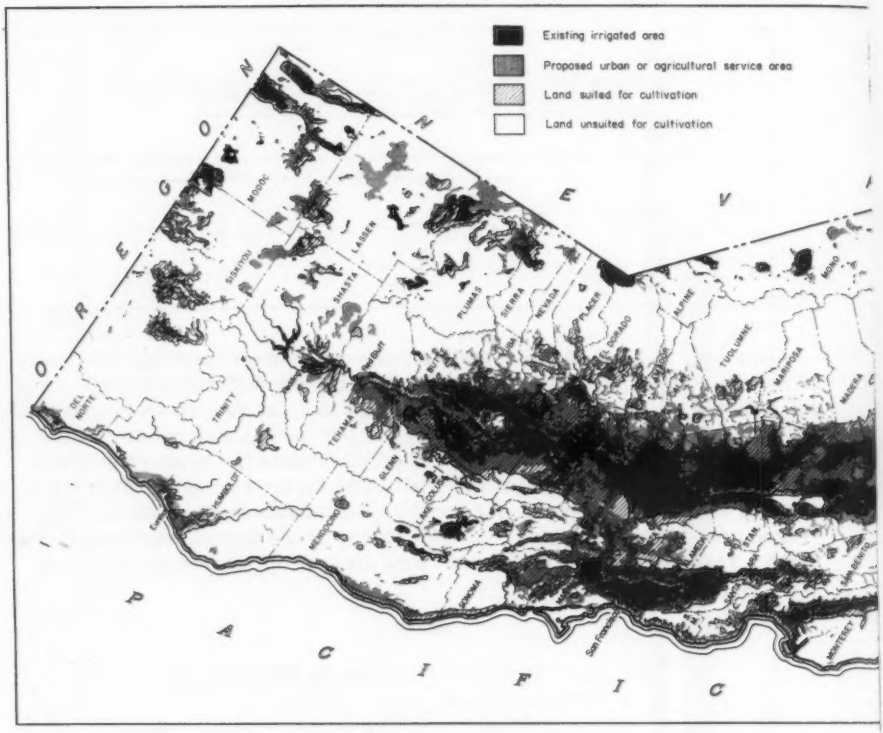


Fig. 4—Comparison of California Water Plan Service Areas and Soil Conservation Service Land Capability Ratings

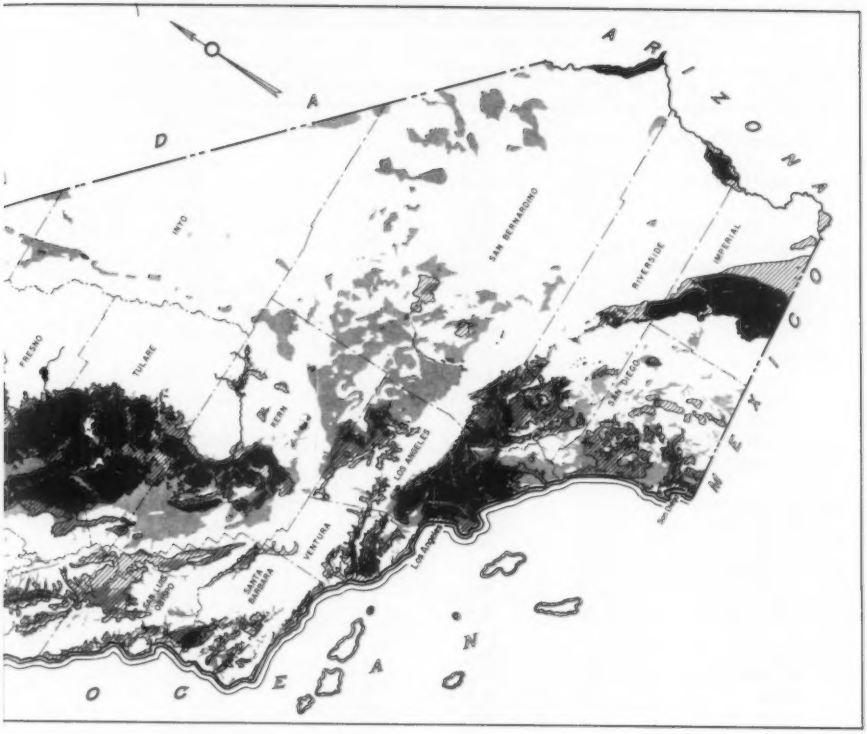

A R I Z O N A
D A
INYO
SAN BERNARDINO
RIVERSIDE
IMPERIAL
FRESNO
TULARE
KERN
SAN DIEGO
LOS ANGELES
VENTURA
SANTA BARBARA
M E X I C O
O C E A N

TABLE 6

Percent Distribution of Personal Income Received by Persons From Farms, Manufacturing and Services in the United States, 1955

State or Region	Farms	Manufacturing	Services
Continental United States	5.9	31.3	11.2
New England	2.2	39.9	11.7
Maine	9.2	32.9	9.3
New Hampshire	3.8	39.2	11.3
Vermont	10.9	30.6	12.3
Massachusetts	1.0	37.6	12.6
Rhode Island	0.9	41.9	10.5
Connecticut	1.8	46.3	11.2
Mideast	1.4	34.1	12.8
New York	1.2	30.1	14.7
New Jersey	1.2	41.3	11.7
Pennsylvania	1.8	40.5	10.2
Delaware	3.8	44.9	9.6
District of Columbia		3.5	18.2
Great Lakes	4.0	42.7	9.3
Michigan	2.2	49.7	8.5
Ohio	2.9	44.5	9.1
Indiana	6.2	44.0	7.5
Illinois	4.0	37.3	10.9
Wisconsin	8.1	39.1	9.0
Plains	13.9	21.6	10.1
Minnesota	12.3	21.7	10.4
Iowa	20.1	21.4	9.1
Missouri	8.9	27.3	10.7
North Dakota	36.5	3.1	8.7
South Dakota	25.3	6.8	9.9
Nebraska	13.5	14.1	10.5
Kansas	9.8	22.1	9.7

Less than ten per cent of those employed in California are engaged directly in agricultural work. The Census of Agriculture reports that during the harvest season in 1954 a total of 277,753 workers were hired but only 22,277 were employed 150 days or more. Expenditures for hired farm labor in 1954 amounted to $410,711,854. By comparison, the Census of Manufacture reports that 771,796 manufacturing workers were employed in California in 1954 and their wages amounted to $3,143,793,000. On a national basis, the average wage per employed factory worker in 1955 was $3,979 while the average annual farm income per worker was $1,711.(4)

Economic Values

Tables 7 through 10 present some comparisons of economic values resulting from utilizing a given amount of water on land and in manufacturing. While some of these data may not be precisely comparable because of the diversity of sources they indicate that in California:

TABLE 6 (Continued)

State or Region	Farms	Manufacturing	Services
Southeast	11.0	24.2	10.8
Virginia	6.1	21.2	10.4
West Virginia	3.4	27.6	7.9
Kentucky	10.8	25.7	10.0
Tennessee	8.9	29.5	10.9
North Carolina	15.3	31.9	9.4
South Carolina	11.6	35.2	9.0
Georgia	9.9	26.9	10.5
Florida	8.8	10.9	15.9
Alabama	11.6	27.6	9.9
Mississippi	26.6	17.8	9.3
Louisiana	7.4	19.6	12.6
Arkansas	26.2	16.7	9.5
Southwest	9.0	16.8	11.3
Oklahoma	7.4	15.4	10.8
Texas	8.7	18.3	11.2
New Mexico	9.3	10.2	12.4
Arizona	14.2	11.4	12.7
Rocky Mountain	11.9	13.3	10.8
Montana	24.2	10.1	9.3
Idaho	19.3	14.8	11.0
Wyoming	12.3	8.5	10.3
Colorado	6.2	14.6	12.2
Utah	6.6	14.8	9.3
Far West	6.3	25.0	12.9
Washington	7.1	24.9	10.5
Oregon	7.7	27.3	11.3
Nevada	4.3	5.3	26.4
California	6.0	25.1	13.2
Territory of Hawaii	13.0	10.9	12.3

1. Manufacturing provides 4.33 times as much personal income per 1,000 gallons of water withdrawn per day as does farming;
2. Farming annually uses 8.6 times as much water per employee per day as does manufacturing;
3. Manufacturing produces 68 times as much product value as farming per 1,000 gallons of water withdrawn per day;
4. Urban land is taxed 8.7 times more than agricultural land per 1,000 gallons of water withdrawn per day.

TABLE 7

Relationship Between Net Value of Production and Water Use in California, 1954

Economic Activity	Water Use (mgd)	Net value of production (millions of $)	Value of production per 1,000 gallons of water withdrawn per day
Farming	23,025	938,600	$ 0.024
Manufacturing	6,280	8,597,453	1.37

TABLE 8

Relationship Between Property Taxes and Water Use in California, 1954

Type of Real Estate	Water Use (mgd)	Taxes Levied	Taxes levied per 1,000 gallons of water withdrawn per day
Farm real estate	23,136	$ 79,219,000	$ 3.42
City real estate	7,570	217,874,551	29.65

TABLE 9

Relationship Between Water Use and Personal Income in California, 1955

Economic Activity	Water Use (mgd)	Personal Income (millions of $)	Personal Income per 1,000 gallons of water withdrawn per day
Farming	23,025	434	$ 0.55
Manufacturing	6,280	5,493	2.38

TABLE 10

Relationship Between Water Use and Employment in California, 1955

Economic Activity	Water Use (million gallons/yr)	Employment (annual average)	Annual Average Employment per 1,000 gallons of water withdrawn
Farming	8,404,125	495,000	1 employee per 16,978
Manufacturing	2,292,200	1,163,000	1 employee per 1,970

The foregoing comparisons by no means suggest that if all of the state's water resources were put to urban and industrial uses instead of into irrigation, California's wealth would be unbounded. Such uses require only comparatively limited quantities. Nor is the vast importance of agriculture impugned by these comparisons. They do, however, provide a basis for judging the economic wisdom of consigning limited water supplies to the irrigation of land without a thorough study of the quality of the land and without carefully considering the possibility that a greater economic good might come from assigning to some competing beneficial use such water as it can utilize efficiently in the production of wealth. This becomes especially critical in view of the irretrievability of water committed to irrigation—both because of the vested rights which go with the commitment and because irrigation water is consumed during use.

Unfortunately the aura of romance surrounding the transformation of desert lands into prosperous farms seems to have dimmed our awareness of the relative capacity of our agriculture and our industry to absorb workers and to further economic growth under conditions existing today. Despite the fact that in many western states farm population is declining, that many farmers rely on urban industry for supplemental income, that the bulk of our working force is concentrated in cities, and that industrial use is rapidly rising, our proposals for water resources development show a scant heed of the necessity for establishing an equilibrium between water use and economic development. While valid criteria for facilitating such economic development in the west may not be found in continued "homesteading" water policies, one conclusion is brought into sharp focus by their apparent effects: A policy of maximum application of water to land will not bring about the highest economic return from this scarce resource. The implication of this conclusion is that the value of water should be measured by its ability to produce desired economic effects. This is the major criterion for the economic evaluation of water which may be drawn from the foregoing considerations.

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METEORIC VS NONMETEORIC GROUND WATER[a]

H. E. Thomas[1] and D. E. White[2]

ABSTRACT

As the demand has increased for surface water and ground water that is replenished by the hydrologic cycle, many have wondered as to the possibilities of developing potable non-meteoric water supplies. However, recent research indicates that practically all juvenile water is too highly mineralized for most uses.

Nearly all scientific reports on ground water are concerned only with meteoric water—that is, water of the hydrologic cycle which involves evaporation, atmospheric circulation, precipitation as rain or snow, and surface and subsurface movement toward the oceans. But what of the water that is not of meteoric origin? Many geologists have described several types of water which have originated by recrystallization, dehydration, compression, cooling, and other processes that are active in the earth's crust. Have we missed a bet by neglecting such possible sources, particularly in areas of short supply where meteoric water is insufficient for all desires, and may all be tied up in water rights and controversies? How exhilerating it would be to tap a source of proved juvenile water, which, by being outside the realm of the hydrologic cycle, might also be deemed to be beyond the realm of established water law!

Admittedly it is not easy to recognize juvenile water—water that has never before appeared at the earth's surface. Although we can distinguish a juvenile from a rejuvenated human being, we are not so well acquainted with water

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a. Publication authorized by the Director, U. S. Geological Survey.

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molecules; however, the distinction is not important, and most of us might well list "juvenile" and "rejuvenated" waters together, both having originated in processes related to rock development. A logical classification of nonmeteoric waters might thus correspond to the broad classification of rock types into igneous, sedimentary, and metamorphic.

As described in a recent paper (White, 1957b), magmatic water is in, or is derived from, magma; it may be called plutonic water if it originates at considerable depth, and volcanic water if it comes from magma at the surface or shallow depth (White, 1957a). Metamorphic water is or has been associated with rocks during their metamorphism, and is probably derived largely from hydrous minerals during recrystallization to anhydrous minerals at depths of many thousands of feet, where temperatures are probably more than 400° F. Connate water is the interstitial water in unmetamorphosed sediments; it is largely or entirely of meteoric origin but has been out of contact with the atmosphere for perhaps millions of years, and during that time it is likely to be changed drastically from the original meteoric water. Presumably there are gradations among these three major types of nonmeteoric waters, just as there are gradations among the major types of rocks.

A basic distinction between meteoric and nonmeteoric waters is suggested by the fact that the hydrologic cycle includes a distillation process of vaporization and precipitation that has no counterpart in the development of nonmeteoric waters, except for volcanic steam. Thus meteoric water is more likely to be fresh—and fresh water is much more likely to be meteoric—than nonmeteoric water. There are of course numerous exceptions notably of meteoric water that has passed through soluble rocks and become highly mineralized; there is little possibility that nonmeteoric waters will not be highly mineralized. This general rule explains why ground-water hydrologists have been concerned especially with meteoric waters—because water users desire fresh water—and why many economic geologists have been interested in the nonmeteoric waters, because of their relation to ore deposits (White, 1955).

Meteoric water might be expected to be dominant at the land surface and down to the level of the streams that provide the drainage of water to the ocean; meteoric waters may also go to far greater depths, according to the rock permeabilities and opportunities for circulation of water, and in some sediments fresh water has been found at depths more than half a mile below sea level. There is a greater chance, however, that deep waters may be of nonmeteoric origin. Much of our present information about deep waters comes from thermal springs, some of which are associated with volcanism, and some of which rise in nonvolcanic areas, presumably from great depths.

As pointed out by White (1957b), some major types of water of deep origin are believed to be recognizable from their chemical composition. Oil-field brines dominated by sodium and calcium chlorides differ markedly from average ocean water. In general, the brines are believed to be connate in origin ("fossil" sea water) and have a proportion of modern meteoric water ranging from negligible to high, depending on degree of flushing. Many brines are much higher in salinity than sea water and are greatly enriched in calcium as well as sodium chloride. Brines whose salinity is near that of sea water are generally higher, relative to sea water, in bicarbonate, iodine, boron, lithium, silica, ammonium, and water-soluble organic compounds, and lower in sulfate, potassium, and magnesium.

Volcanic waters are similar in some respects to connate waters but are believed to be distinguishable by much higher temperature and associated heat flow; by relatively high contents of lithium, fluorine, silica, boron, sulfur, CO_2, arsenic, and antimony; by relatively low calcium and magnesium; and by lack of hydrocarbons, water-soluble organic compounds, and perhaps ammonia and nitrate. Relatively high boron and combined CO_2 alone are not reliable indicators of a volcanic origin.

During the compaction that accompanies deep burial of sedimentary rocks, the rocks lose most of their interstitial high-chloride water. Much additional water may then be lost during progressive metamorphism, and the water content changes from about 5 per cent in shale to perhaps 1 per cent in the highly metamorphosed rock called gneiss. The expelled water has been called "metamorphic." Because normally pressure increases downward and permeability of deeply buried rocks increases upward, the water generally must escape upward and mix with connate and meteoric water. Even though large quantities of it must exist, no example of metamorphic water has been positively identified.

Recent studies of the isotopes of hydrogen—tritium (T or H^3) and deuterium (D or H^2)—and of oxygen (O^{18}) have provided important new tools for determinations of the origin of ground water. Finding tritium in a water sample would be conclusive evidence that the water is meteoric, at least in part, for the tritium originates chiefly by action of cosmic rays upon the nitrogen atoms of the atmosphere—and, recently as a byproduct of the hydrogen bombs, distributed worldwide by atmospheric circulation. However, because tritium has a half-life of only 12.4 years, the tritium content of meteoric water becomes too low to be measurable after the water has been isolated from the atmosphere for more than about 50 years; thus, absence of tritium is not proof of nonmeteoric origin of water as meteoric ground waters are commonly more than 50 years old. On the other hand, its presence is not proof that the sample is entirely of meteoric origin.

The relative concentrations of deuterium and O^{18} also may be of value in identifying the origin of water. The evidence from analyses of these constituents made to date indicates that the water from most thermal springs is predominantly if not exclusively meteoric. The average ocean water is made up of about 99.77 per cent of H_2O^{16}, 0.03 per cent HDO^{16}, 0.20 per cent H_2O^{18}, and a minute percentage of molecules containing tritium. Since H_2O^{16} is the most volatile of the three most common water molecules, ocean waters should have high concentrations of the heavy isotopes, whereas terrestrial fresh waters should be relatively depleted of these isotopes. This pattern is well confirmed experimentally. Craig, Boato, and White (1956) report that, in several hundred samples of water from snow, rain, rivers, and lakes, the deuterium concentration varies by about 30 per cent, ranging from 3 per cent higher to 27 per cent lower than that in average ocean water, and the O^{18} concentration varies by 4 per cent, ranging from 0.6 per cent higher to 3.4 per cent lower than that in average ocean water; the depletions in both isotopes show a general correlation with distance from the ocean, and there is a general decrease in heavy-isotope concentration with increasing latitude, reflecting the continuous loss of vapor from the poleward-moving air masses. In a few highly evaporated waters, generally in lakes having little or no external discharge, the water is "heavier" than that in the ocean. In any given area the average meteoric water is likely to be isotopically different from the meteoric waters of other areas; and any deep water of nonmeteoric origin that is rising

to the surface is especially likely to be very different isotopically from the meteoric water that happens to characterize the area into which it rises.

As Craig, Boato, and White point out (p. 33-35):

> ". . . Thermal waters show a strict dependence on the isotopic composition of the local surface water. They display a knowledge of the local climatic conditions on the earth's surface, knowledge of which magmatic waters should surely be ignorant . . . We have no positive isotopic evidence for any juvenile or magmatic water in any of the hot spring systems we have studied."

In a later paper White (1957a) finds that magma is required as a source of the observed temperatures and calculated heat flow in the thermal springs of many volcanic areas, and he concludes that even in these volcanic areas the thermal waters have a volcanic component that probably does not exceed 5 to 10 per cent of the total. That is, he concludes that meteoric water circulates to great depths and in places mixes with a small proportion of magmatic water. Thus the thermal waters of some of our best known volcanic areas, such as Yellowstone Park, are predominantly of meteoric rather than magmatic origin.

In contrast, the highly mineralized connate water of oil fields and the water of some saline springs are very different isotopically from the meteoric waters occurring at and near the surface of the same areas (White, 1957b, p. 1666-1667). These mineral waters can have mixed but little with modern meteoric water.

During a recent conference on nuclear process, Harmon Craig (Craig, Boato, and White, 1956) summarized the present status of istopic geochemistry:

> ". . . With our present knowledge we could not distinguish magmatic water of original oceanic origin from truly juvenile water. Furthermore, a low tritium content is not, of course, unequivocal, since one cannot thus distinguish between dead rain water and juvenile water mixing in. The most important thing is to combine stable and radioactive isotope studies on problems of this kind, and use as many isotopes in conjunction as you can. Then you really begin to hit hard at questions such as sources, rates, and so forth, and you have a really powerful tool."

White (1957a, p. 1642; 1957b, p. 1663, 1674-1679) also has shown that any large supply of water actively flowing to the surface from great depth must be anomalously high in temperature. In general, temperature rises about 1° F per hundred feet below the surface. A small quantity of water could rise very slowly from depth and lose most of its heat by conduction, but water of large rate of flow should arrive at the surface with most of its original heat content.

Thus, the evidence seems clear that fresh water of low temperature is virtually certain to be entirely or almost entirely of meteoric origin. Future study of isotopes may be expected to substantiate this interpretation.

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WATER—A LIMITING RESOURCE?[a]

Closure by Robert O. Thomas

ROBERT O. THOMAS,[1] M. ASCE.—It is indeed gratifying that three such eminent authorities as Messrs. Woodward, Golze, and Baker have contributed, with general endorsement of the thesis, to the discussion of the original paper. It is regretted that a greater expression of opinion was not forthcoming from the profession. It is felt that the lack of widespread discussion may have possibly been due to the failure of the paper to communicate adequately the intended message. It appears that the purpose and intent of the paper were unclear, since some aspects of the discussions indicate misunderstanding of the character of the essay. Opportunity will be taken in this closure to elaborate on some of the questioned aspects.

To begin with, it was stated that the paper was written to "evoke wide discussion of the implications inherent in the apparent adverse balance between supply and probable demand, and to engender recommendations for present and future action". The paper concluded with a prediction of a demand approximating 93% of the average annual supply when a population of 450,000,000 was attained in this country. The basic purpose of a "view with alarm" essay is, of course, to emphasize the implications of the problem posed, on a consciously generalized basis, in order to reinforce the claim of immediacy in ascertaining the solution. It was felt that thereby the door was left open for discussers to point out:

a. The population of the country is increasing at a rapid rate.
b. The increase may exhaust our water supplies if past trends of excessive and improvident use continue into the future.
c. The actual year of exhaustion, whether it be 2070, 2170, or 2270, matters very little. The important point that must be faced is the prospect of exhaustion.
d. Nevertheless, the population must be provided with a place to live; with shelter, food, and clothing; and with employment, which implies basic, as well as processing, industry and services.
e. The maximum amount of natural fresh water which can be made available may only be about one-half the predicted demand.
f. Therefore, we must start now to study and plan so that the solution may be available when needed.

Additionally, it was felt that the implications were sufficiently serious and immediate to require conscious and intensive effort in arriving at the solution. It is suggested that a program such as the following may be appropriate:

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a. Proc. Paper 1754, September, 1958, by Robert O. Thomas.
1. Sacramento, Calif.

1. An immediate start on comprehensive planning, by the states or by the federal government in cooperation with the states, for each river basin. This would determine, with full consideration to topography, availability of surface and underground storage capacity, quantity and variation of water supply, and requirements of all competing uses, the maximum quantity of water which can be conserved in the individual basins. This quantity will probably vary in the range of 40 to 75 per cent of the average annual supply. The sum of this quantity, for the nation, would be the maximum quantity which we can plan on using. The actual quantity which can be put to use may be somewhat less, due to difficulties that might be encountered in effecting distribution.
2. The availability and capability of the land and other resources of each river basin, together with their ability to support a population and effect beneficial use of the basin water supplies, must also be determined. This will enable determination of the availability of excess supplies, permitting export of the surplus; or of deficiencies, requiring import to meet demand.
3. The physical and economic considerations affecting possible exports and imports will then be studied. This will result in the master plan for utilization of our natural, or meteoric, water resources.
4. Finally, we will be able to predict, with a fair degree of certainty, the quantity of water which must be secured from other sources, such as the oceans, and the location and nature of the uses which will be made of such supplies.

It is felt that an appreciable length of time is necessary to make the detailed studies outlined above and that the extension of present use trends into the forseeable future, say 40 to 50 years, is such that we may already have passed the time when this work should have been initiated.

Mr. Woodward takes exception to the estimate of 1.25 acre-feet per acre required in the humid areas, and to the prediction of a demand for 124 million acre-feet per year. It is pointed out that the 1.25 acre-feet per acre includes the return water allowance (irrigation efficiency) and that the estimated total is really of little moment at this time. What is important is the realization that the requirement will be huge, even if only one-half or two-thirds of the estimated quantity, and plans should now be started to meet the requirement when it occurs.

Mr. Woodward has misinterpreted the statement relative to the value of irrigated and dry-farmed crops. The conclusion, as given in the paper, was "irrigated acreage will produce twice the value of dry-farmed acreage". The fact that available data on irrigation pertains principally to the semi-arid zone does not impute "semi-arid" to the conclusions drawn.

Mr. Woodward has justly pointed out that some types of land use may be subject to critical review and analysis. This view is certainly concurred in, and may be an appropriate aspect of study in connection with the suggested point (9)—"Integration of the economies of the United States and Canada . . ." While full agreement cannot be given to the implication that forestation might be a low-value use, it may well be that many lands now devoted to production of forest products might better be used for food production while forestry is practiced in more barren or less easily accessible areas.

Mr. Golze's initial points are covered in the introductory material to this closure, in which the scope of studies required to provide the basis for

intelligent and competent planning is briefly presented. On the subject of demineralization of saline waters, it is respectfully submitted that opinion as to the sufficiency of present activities of the Office of Saline Water is entirely subjective. The writer definitely feels that they should be augmented considerably. So far as authorization of pilot plants by Congress is concerned, an unduly long time often elapses between "authorization" and "appropriation."

The suggestion for integration of the economies of the United States and Canada goes to objectives far beyond the scope of boundary commissions or treaties dividing the waters of international streams. Although the pages of a technical journal are not the proper place for critical analyses of foreign policy, it is felt that some United States actions, such as selling surplus crops on the world market at prices depriving Canadian farmers of the opportunity for profitable sale of farm produce; import controls on certain metals which, in 1958, resulted in dislocating reductions in the Canadian minerals industry; and the very recent petroleum curbs, in the name of national defnese, that has caused Canada to point out that much of our defense depends upon that nation's acquiescence and well-being, can scarcely be considered to promote cooperation and friendship. The vast expanse of Canada contains tremendous mineral, land, and water resources which, when combined with the population and other resources of the United States, could result in appreciable benefits to both nations. Therefore, the words "integration" and "economies" in reference to the United States and Canada were meant to imply the maximum of cooperative effort in each and every aspect of human endeavor.

With regard to Mr. Golze's final point, it has been officially stated(1) that the annual overdraft on developed water resources of California amounted, in 1955, to about 4,000,000 acre-feet. Assuming that, if the Feather River and Delta Diversion Projects were given major impetus and financing this year (1959), the water provided could be delivered by 1970, an eleven-year construction period; and further assuming that the annual overdraft by that date would only approximate 6,000,000 acre-feet; and further assuming that the cumulative overdraft in 1955 (although figures are not readily available) amounted to only 15,000,000 acre-feet; the accumulative overdraft by the time delivery of project water occurred would be 90,000,000 acre-feet—no small quantity of water. Yet, the water made available by the presently authorized project is of the order of 4,000,000 acre-feet per year, about equal to the 1955 overdraft. It is felt that similar situations, in principle although not in magnitude, are occurring in other sections of the country. It is believed that the ten-year comprehensive, detailed study which resulted in The California Water Plan, and from which the foregoing conclusions are derived, is both singular and unique in this country. It is suggested that many other regions might be surprised and astonished at the answers which might be derived from similar studies.

It is felt that most of Mr. Baker's comments have already been answered, at least in part. However, with regard to the magnitude of hydro-electric generation, two aspects seem worthy of mention. First, the estimate of hydro power increased from 115 billion kwh to 270 billion kwh, an appreciable gain in itself. Second, the fluctuation of demand for hydro power, unless ample re-regulation facilities are provided, is alternatively competitive to timing of demand accruing from many other uses of water. Since power may be produced by substitute facilities, it was assumed the power considerations would be secondary to other demands for use of water supplies.

In general, the discussors approved the principal ideas expressed in the paper. This closure is in no sense critical of the points raised as it is felt that such criticism undoubtedly resulted from failure of the author to present his major premises in a clear and adequate manner.

REFERENCES

1. California Department of Water Resources, Bulletin No. 3, "The California Water Plan", May, 1957, page 16.

UPSTREAM IRRIGATION IMPACT ON COLUMBIA RIVER FLOWS[a]

Discussion by Raphael G. Kazmann

RAPHAEL G. KAZMANN,[1] M. ASCE.—This paper furnishes a good overall picture of the role of upstream irrigation in the reduction of peak flows of the Columbia River and in the possible increase of low flows. If the writer's understanding of the gross figures are correct, for 5 million acres of irrigated land the net consumptive use of water would be about 10 million AF/yr and the expected maximum would be about 17 million AF/yr—a minor percentage of the 121 million AF/yr which was, on the average, available.

Using the gross delivery figures this would mean the diversion, during a 100-day irrigation season, of about 150,000 cfs at present and about 230,000 cfs ultimately. These gross figures must be compared with the average flow of about 350,000 cfs at the Dalles during the growing season.

The difficulty is that all of these figures are averages. Whereas the key question for a farmer, and for an irrigation project, is the adequacy of the water supply during the critical drought years.

Therefore it would be most desirable, and would add to the value of this paper, if the author would indicate in his closure the computed effect of the present and the maximum probable future diversion upon the recorded monthly flow of the Columbia River during the driest year on record. Inasmuch as a water supply system can be best appraised on the basis of operation during dry periods, the information presented in the paper should be supplemented to elucidate the water supply and hydro-power situation during the critical year, or years.

Another subject that would be desirable for the author to enlarge upon is the statement that the "major part of the water supply to irrigate the 19,000 acre Kennewick Division of the Yakima Project . . . is return flow by virtue of irrigation of 450,000 acres on upstream divisions of the Yakima Project." The author states that "the Yakima Project diverted about . . . 6 AF/acre". Even allowing for a consumptive use averaging as much as 3 AF/acre, this would leave a total of about 1.1 million acre-feet designated as "return flow" —a supply adequate to furnish water for about 175,000 acres. The Kennewick Division is only 19,000 acres in irrigated area. Is information available as to what happened to the water not used by Kennewick? How is the return flow from the irrigation projects distributed throughout the year? Answers to these questions and a description of the techniques used in obtaining them would be useful to the profession as well as to the planners of similar projects.

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a. Proc. Paper 1965, March, 1959, by Harold T. Nelson.

1. Cons. Engr., Stuttgart, Arkansas.

PROCEEDINGS PAPERS

The technical papers published in the past year are identified by number below. Technical-division sponsorship is indicated by an abbreviation at the end of each Paper Number, the symbols referring to: Air Transport (AT), City Planning (CP), Construction (CO), Engineering Mechanics (EM), Highway (HW), Hydraulics (HY), Irrigation and Drainage (IR), Pipeline (PL), Power (PO), Sanitary Engineering (SA), Soil Mechanics and Foundations (SM), Structural (ST), Surveying and Mapping (SU), and Waterways and Harbors (WW), divisions. Papers sponsored by the Department of Conditions of Practice are identified by the symbols (PP). For titles and order coupons, refer to the appropriate issue of "Civil Engineering." Beginning with Volume 82 (January 1956) papers were published in Journals of the various Technical Divisions. To locate papers in the Journals, the symbols after the paper number are followed by a numeral designating the issue of a particular Journal in which the paper appeared. For example, Paper 1859 is identified as 1859 (HY 7) which indicates that the paper is contained in the seventh issue of the Journal of the Hydraulics Division during 1958.

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JUNE: 1658(AT1), 1659(AT1), 1660(HY2), 1661(HY3), 1662(HY3), 1663(HY3), 1664(HY3), 1665(SA3), 1666(PL2), 1667(PL2), 1668(PL2), 1669(AT1), 1670(PO3), 1671(PO3), 1672(PO3), 1673(PL2), 1674(PL2), 1675(PO3), 1676(PO3), 1677(SA3), 1678(SA3), 1679(SA3), 1680(SA3), 1681(SA3), 1682(SA3), 1683(PO3), 1684(HY3), 1685(SA3), 1686(SA3), 1687(PO3), 1688(SA3)[c], 1689(PO3)[c], 1690(HY3)[c], 1691(PL2)[c].

JULY: 1692(EM3), 1693(EM3), 1694(ST4), 1695(ST4), 1696(ST4), 1697(SU2), 1698(SU2), 1699(SU2), 1700(SU2), 1701(SA4), 1702(SA4), 1703(SA4), 1704(SA4), 1705(SA4), 1706(EM3), 1707(ST4), 1708(ST4), 1709(ST4), 1710(ST4), 1711(ST4), 1712(ST4), 1713(SU2), 1714(SA4), 1715(SA4), 1716(SU2), 1717(SA4), 1718(EM3), 1719(EM3), 1720(SU2), 1721(ST4)[c], 1722(ST4), 1723(ST4), 1724(EM3)[c].

AUGUST: 1725(HY4), 1726(HY4), 1727(SM3), 1728(SM3), 1729(SM3), 1730(SM3), 1731(SM3), 1732(SM3), 1733(PO4), 1734(PO4), 1735(PO4), 1736(PO4), 1737(PO4), 1738(PO4), 1739(PO4), 1740(PO4), 1741(PO4), 1742(PO4), 1743(PO4), 1744(PO4), 1745(PO4), 1746(PO4), 1747(PO4), 1748(PO4), 1749(PO4).

SEPTEMBER: 1750(IR3), 1751(IR3), 1752(IR3), 1753(IR3), 1754(IR3), 1755(ST5), 1756(ST5), 1757(ST5), 1758(ST5), 1759(ST5), 1760(ST5), 1761(ST5), 1762(ST5), 1763(ST5), 1764(ST5), 1765(WW4), 1766(WW4), 1767(WW4), 1768(WW4), 1769(WW4), 1770(WW4), 1771(WW4), 1772(WW4), 1773(WW4), 1774(IR3), 1775(IR3), 1776(SA5), 1777(SA5), 1778(SA5), 1779(SA5), 1780(SA5), 1781(WW4), 1782(SA5), 1783(SA5), 1784(IR3)[c], 1785(WW4)[c], 1786(SA5)[c], 1787(ST5)[c], 1788(IR3), 1789(WW4).

OCTOBER: 1790(EM4), 1791(EM4), 1792(EM4), 1793(EM4), 1794(EM4), 1795(HW3), 1796(HW3), 1797(HW3), 1798(HW3), 1799(HW3), 1800(HW3), 1801(HW3), 1802(HW3), 1803(HW3), 1804(HW3), 1805(HW3), 1806(HY5), 1807(HY5), 1808(HY5), 1809(HY5), 1810(HY5), 1811(HY5), 1812(SM4), 1813(SM4), 1814(ST6), 1815(ST6), 1816(ST6), 1817(ST6), 1818(ST6), 1819(ST6), 1820(ST6), 1821(ST6), 1822(EM4), 1823(PO6), 1824(SM4), 1825(SM4), 1826(SM4), 1827(ST6)[c], 1828(SM4)[c], 1829(HW3)[c], 1830(PO6)[c], 1831(EM4)[c], 1832(HY5)[c].

NOVEMBER: 1833(HY6), 1834(HY6), 1835(SA6), 1836(ST7), 1837(ST7), 1838(ST7), 1839(ST7), 1840(ST7), 1841(ST7), 1842(SU3), 1843(SU3), 1844(SU3), 1845(SU3), 1846(SU3), 1847(SA6), 1848(SA6), 1849(SA6), 1850(SA6), 1851(SA6), 1852(SA6), 1853(SA6), 1854(ST7), 1855(SA6)[c], 1856(HY6)[c], 1857(ST7)[c], 1858(SU3)[c].

DECEMBER: 1859(HY7), 1860(IR4), 1861(IR4), 1862(IR4), 1863(SM5), 1864(SM5), 1865(ST8), 1866(ST8), 1867(ST8), 1868(PP1), 1869(PP1), 1870(PP1), 1871(PP1), 1872(PP1), 1873(WW5), 1874(WW5), 1875(WW5), 1876(WW5), 1877(CP2), 1878(ST8), 1879(ST8), 1880(HY7)[c], 1881(SM5)[c], 1882(ST8)[c], 1883(PP1)[c], 1884(WW5)[c], 1885(CP2)[c], 1886(PO6), 1887(PO6), 1888(PO6), 1889(PO6), 1890(HY7), 1891(PP1).

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JANUARY: 1892(AT1), 1893(AT1), 1894(EM1), 1895(EM1), 1896(EM1), 1897(EM1), 1898(EM1), 1899(HW1), 1900(HW1), 1901(HY1), 1902(HY1), 1903(HY1), 1904(HY1), 1905(PL1), 1906(PL1), 1907(PL1), 1908(PL1), 1909(ST1), 1910(ST1), 1911(ST1), 1912(ST1), 1913(ST1), 1914(ST1), 1915(ST1), 1916(AT1)[c], 1917(EM1)[c], 1918(HW1)[c], 1919(HY1)[c], 1920(PL1)[c], 1921(SA1)[c], 1922(ST1)[c], 1923(EM1), 1924(HW1), 1925(HW1), 1926(PL1), 1927(HW), 1928(HW1), 1929(SA1), 1930(SA1), 1931(SA1), 1932(SA1).

FEBRUARY: 1933(HY2), 1934(HY2), 1935(HY2), 1936(SM1), 1937(SM1), 1938(ST2), 1939(ST2), 1940(ST2), 1941(ST2), 1942(ST2), 1943(ST2), 1944(ST2), 1945(HY2), 1946(PO1), 1947(PO1), 1948(PO1), 1949(PO1), 1950(HY2)[c], 1951(SM1)[c], 1952(ST2)[c], 1953(PO1)[c], 1954(CO1), 1955(CO1), 1956(CO), 1957(CO1), 1958(CO1), 1959(CO1).

MARCH: 1960(HY3), 1961(HY3), 1962(HY3), 1963(IR1), 1964(IR1), 1965(IR1), 1966(IR1), 1967(SA2), 1968(SA2), 1969(ST3), 1970(ST3), 1971(ST3), 1972(ST3), 1973(ST3), 1974(ST3), 1975(ST3), 1976(WW1), 1977(WW1), 1978(WW1), 1979(WW1), 1980(WW1), 1981(WW1), 1982(WW1), 1983(WW1), 1984(SA2), 1985(SA2)[c], 1986(IR1)[c], 1987(WW1)[c], 1988(ST3)[c], 1989(HY3)[c].

APRIL: 1990(EM2), 1991(EM2), 1992(EM2), 1993(HW2), 1994(HY4), 1995(HY4), 1996(HY4), 1997(HY4), 1998(SM2), 1999(SM2), 2000(SM2), 2001(SM2), 2002(ST4), 2003(ST4), 2004(ST4), 2005(ST4), 2006(PO2), 2007(HW2)[c], 2008(EM2)[c], 2009(ST4)[c], 2010(SM2)[c], 2011(SM2)[c], 2012(HY4)[c], 2013(PO2)[c].

MAY: 2014(AT2), 2015(AT2), 2016(AT2), 2017(HY5), 2018(HY5), 2019(HY5), 2020(HY5), 2021(HY5), 2022(HY5), 2023(PL2), 2024(PL2), 2025(PL2), 2026(PP1), 2027(PP1), 2028(PP1), 2029(PP1), 2030(SA3), 2031(SA3), 2032(SA3), 2033(SA3), 2034(ST5), 2035(ST5), 2036(ST5), 2037(ST5), 2038(PL2), 2039(PL2), 2040(AT2)[c], 2041(PL2)[c], 2042(PP1)[c], 2043(ST5)[c], 2044(SA3)[c], 2045(HY5)[c], 2046(PP1), 2047(PP1).

JUNE: 2048(CP1), 2049(CP1), 2050(CP1), 2051(CP1), 2052(CP1), 2053(CP1), 2054(CP1), 2055(CP1), 2056(HY6), 2057(HY6), 2058(HY6), 2059(IR2), 2060(IR2), 2061(PO3), 2062(SM3), 2063(SM3), 2064(SM3), 2065(ST6), 2066(WW2), 2067(WW2), 2068(WW2), 2069(WW2), 2070(WW2), 2071(WW2), 2072(CP1)[c], 2073(IR2)[c], 2074(PO3)[c], 2075(ST6)[c], 2076(HY6)[c], 2077(SM3)[c], 2078(WW2)[c].

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c. Discussion of several papers, grouped by divisions.

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IR2

JUNE 1959 — 23 NO. IR 2
VOLUME 85 PART 2

Your attention is invited

NEWS OF THE IRRIGATION AND DRAINAGE DIVISION OF ASCE

JOURNAL OF THE IRRIGATION AND DRAINAGE DIVISION
PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

DIVISION ACTIVITIES

IRRIGATION AND DRAINAGE DIVISION

Proceedings of the American Society of Civil Engineers

NEWS

June, 1959

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William W. Donnan, Secretary
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Prof. N. A. Christensen, (Cornell University)
412 Haushaw Road, Ithaca, New York

Finley Laverty, Contact Member from Board of Direction
P. O. Box 2418, Terminal Annex, Los Angeles, Calif.

* * *

Carl R. Wilder, Newsletter Editor
3223 So. Columbine St., Denver 10, Colo.

Calendar of Coming Meetings

July 1-3, 1959. Annual Conference, Hydraulics Division, ASCE. Colorado State University, Fort Collins, Colo. Includes field trips to USBR Hydraulic Laboratory, Denver, on June 29, and over Colorado-Big Thompson irrigation project on June 30.

August 24-29, 1959. 8th Congress of International Association for Hydraulic Research. Ecole Polytechnique, Montreal, Quebec, Canada.

August 27-29, 1959. Annual technical conference, Irrigation and Drainage Division, ASCE. Albany Hotel, Denver, Colo.

Note: No. 1959-23 is part of the copyrighted Journal of the Irrigation and Drainage Division, Proceedings of the American Society of Civil Engineers, Vol. 85, IR 2, June, 1959.

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October 19-23, 1959. National Convention, ASCE, Hotel Statler, Washington, D. C. Irrigation and Drainage Division plans to sponsor three or four half-day sessions on the theme, "Irrigation Around the World."

March 7-11, 1960. National Convention, ASCE. Jung Hotel, New Orleans, La. Irrigation and Drainage Division tentatively plans to hold three half-day sessions on: Irrigation and drainage in humid areas; Humid area water rights; and drainage.

Get in touch with one of the following members of our committee on Sessions Programs if you would like to offer a paper or discussion at any of these or other I. & D. programs.

Kenneth Q. Volk, Chairman, 7024 Melrose Ave., Los Angeles, Calif.
N. A. Christensen, 712 Haushaw Road, Ithaca, N. Y.
Governor George D. Clyde, 1747 Browning Ave., Salt Lake City, Utah.
Dr. O. W. Israelsen, 485 East 6th North St., Logan, Utah
Herbert E. Prater, 2001 So. Madison St., Denver 10, Colo.

Chairmen of other standing committees of the Irrigation and Drainage Division are:

Committee on Publications: Dean F. Peterson, Jr., Utah State University, Logan, Utah.

Committee on Cooperation with Local Section: S. Mark Davidson, 2432 So. Jasmine St., Denver 22, Colo.

Committee on Consolidation and Progressive Betterment of Old Irrigation Systems: A. Alvin Bishop, Utah State University, Logan, Utah

Committee on Drainage of Irrigated Lands: Charles R. Maierhofer, 666 Marion St., Denver 18, Colo.

Committee on Ground Water: Harvey O. Banks, Dept. of Water Resources, Sacramento, Calif.

Committee on Irrigation and Drainage Practices in Humid Areas: Marion C. Boyer, 1330 W. Michigan St., Room 377, Indianapolis, Indiana

Task Group on Water Rights Laws in States in Humid Areas: James I. Seay, Jr., 516 Goodwyn Inst. Bldg., Memphis, Tennessee.

Committee on Research: Gerald B. Keesee, Bureau of Indian Affairs, Box 912, Gallup, N. M.

Committee on Water Supply and Conservation: Harry F. Blaney, 215 West 7th St., Los Angeles 14, Calif.

Task Group on Methods of Conserving Water: Arthur E. Bruington, 636 W. Hermosa Ave., San Gabriel, Calif.

Task Group on Consumptive Use of Water by Irrigated Crops and Native Vegetation: Harry F. Blaney.

Task Group on Re-Use of Drainage Water and Water Reclamation: Lloyd E. Myers, Jr., Box 815C, Route 2, Tempe, Arizona.

Task Group on Water Management: Charles W. Thomas, 19 Cowper Street, Berkeley, Calif.

Task Group on Water Quality: P. H. McGauhey, 6819 Snowden Ave., El Cerritto, Calif.

These men are constantly in need of help from other society members. Why not volunteer your talents to the one heading the committee that is working in your field of interest?

* * *

The Executive Committee met in Los Angeles during the February National Convention. Most of the deliberations and decisions were concerned in some way with programs sponsored by the I. & D. Division or activities of its committees.

* * *

All members of this division soon will be receiving definite information on the August 27-29 conference in Denver. This meeting will be jointly sponsored by our division of ASCE and the American Meteorological Society. The overall theme is: "Weather Modification by Artificial Means." General Co-chairmen of the conference will be Dr. Christensen, representing this division, and Robert D. Elliott, President, North American Weather Consultants, Goleta, Calif., representing the AMS. Local chairman is Robert L. Mueller, president of the Colorado Section I. & D. Division.

Four half-day technical sessions are scheduled for the Denver portion of the conference, and plans are being made for an all-day field trip to the High Aititude Observatory near Climax. This trip will not only be interesting from a professional standpoint but also will give visitors an opportunity to see some of America's finest mountain scenery.

It isn't too early for you to make plans to spend a part of your 1959 vacation in Colorado, taking in this conference and also Colorado's "Rush to the Rockies" Centennial Celebration, which will be in full swing in August. Many of you will recall the very profitable and enjoyable division conference held in Denver in September 1955. You may be assured that Colorado hospitality in this "Rush to the Rockies" centennial year will be equally good.

* * *

Charles R. Maierhofer, Chief of the Office of Drainage and Groundwater Engineering, Bureau of Reclamation, Denver, has been elected chairman of the Executive Committee of the U. S. National Committee, International Commission on Irrigation and Drainage. Other members of ASCE who recently were elected to serve on the Executive Committee of this organization are: Wendell E. Johnson, C. J. McKnight, James H. Stratton and R. J. Tipton.

At the time of this writing, plans for the first Triennial Conference of USICID to be held in Reno, Nevada, May 11 and 12 were substantially completed. Members of ASCE on the program of this conference include:

John F. Bonner, PG&E, San Francisco; R. J. Tipton and Olin Kalmbach, Denver; Harry W. Adams and Preston T. Bennett, Corps of Engineers; Lloyd E. Myers, Jr., Agricultural Research Service; Walter U. Garstka and Ray J. Winger, Jr., Bureau of Reclamation; and Gen. Stratton, TAMS, New York.

Programming of this conference was arranged by the Technical Activities Committee of USICID whose chairman is C. W. Thomas, M. ASCE.

* * *

The March Newsletter contained a listing of the members of the Water Supply and Conservation Committee, whose chairman is Harry F. Blaney. Herewith is a detailed statement on the purposes of this committee and its five task groups.

Water Supply and Conservation Committee

Purpose: To study and report on problems connected with the conservation of water supplies principally for irrigation; to promote the collection and compilation of data pertaining to water conservation, giving particular attention to the following:

(a) Methods of conserving water;
(b) Consumptive use of water for irrigated crops and native vegetation;
(c) Re-use of drainage water;
(d) Watershed management;
(e) Water quality;

and to act as a clearing house for the coordination and dissemination of information on these subjects at meetings and Division conferences.

Task Group on Consumptive Use of Water for Irrigated Crops and Native Vegatation

Purpose: To assemble and codify all known consumptive use measurements and all known empirical methods for estimating consumptive use unit values with a view to the preparation of a manual for determining consumptive use of water primarily for irrigation purposes in various areas of the World.

Task Group on Methods of Conserving Water

Purpose: To make a comparative study of various methods of conserving water primarily for irrigation purposes, such as storage in surface reservoirs and underground reservoirs to study the design and cost of water spreading control structures; and to promote work on evaporation suppression.

Task Group on Re-Use of Drainage Water

Purpose: To develop and disseminate information relative to the sources of waste waters suitable for reclamation and to be used primarily for irrigation purposes; and to set forth the principles, methods and practices for reclaiming and utilizing such waters for the irrigation of agricultural lands.

Task Group on Water Quality

Purpose: To initiate a study of methods for the maintenance of water quality primarily for irrigation uses and a study of problems and technical methods of restoring quality of irrigation and drainage water.

Task Group on Watershed Management

Purpose: To make a study of the impact of man-made developments on the natural regimen of watersheds such as modification of weather, vegetation cover, suburban encroachment, and lined channels all of which influence the total available water supply for irrigation purposes.

* * *

The March 1959 joint meeting of the Hydraulics and Irrigation and Drainage Divisions of the Colorado Section was sponsored by the former. They presented Earl Mosley, M. ASCE, Project Engineer for the Denver Water Board, who described the planning, design and construction of the 23.3-mile long Harold D. Roberts tunnel. This concrete-lined tunnel, expected to cost upwards of $50 million, will be capable of transporting an estimated 150,000 acre-feet of water annually from the Blue River, just west of the Continental Divide, to the Denver area. Driving of the tunnel is progressing from four headings; one at each end, and two from a vertical shaft about half way between the west adit and the divide. Mosley also described other tunnel conduit, and treatment and storage facilities that are currently under construction.

The April meeting was sponsored by the I. & D. Division. Howard Curtis, Chief of the Canals and Pipelines Section, Bureau of Reclamation, discussed the Bureau's experiences with underground pipe irrigation systems. That agency has designed and supervised the construction of thousands of miles of systems utilizing low-head unreinforced concrete pipe and high pressure steel and concrete cylinder pipe. Curtis also described recently developed methods of constructing unreinforced cast-in-place pipe. During the past twelve years Curtis' section has designed over 1200 miles of pipe irrigation systems to serve 290,000 acres in 9 districts in California alone. He forecast increased demands from irrigation interests elsewhere for underground water distribution systems.

The May 1959 meeting of these two divisions is to present a talk, "Groundwater in the Denver Basin," by George Chase of the U. S. Geological Survey.

Are any other sections sponsoring programs on irrigation or drainage? Let us know so we can publicize your activities.

* * *